Space Launch System

The Future of Exploration

Sharon Cobb, Ph.D., Assistant Program Manger
Space Launch System
NASA Marshall Space Flight Center
B.S., M.S., Materials Engineering, University of Alabama in Birmingham

November 7, 2013

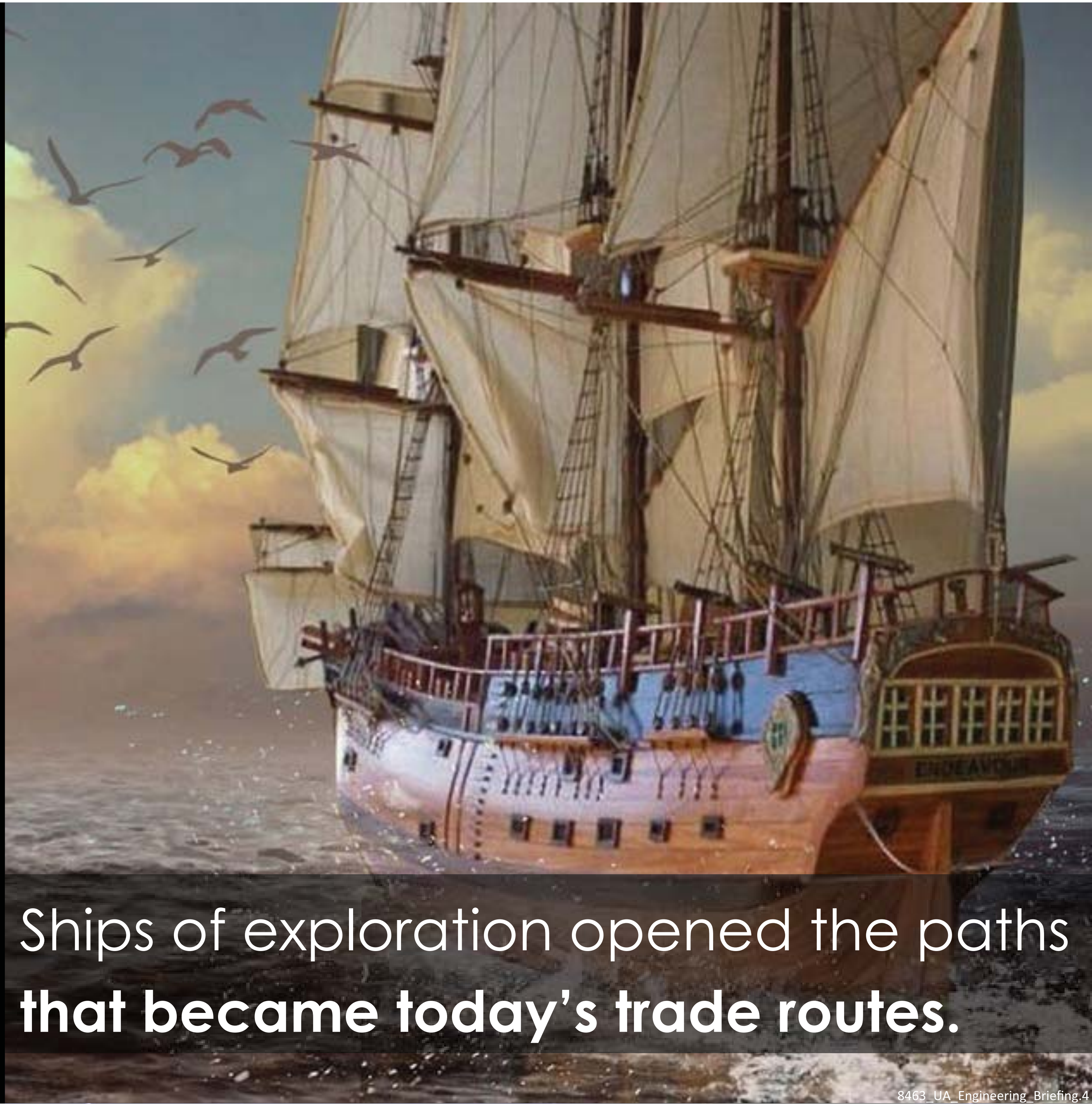
[redacted]

A Deeper Purpose, **A Bolder Mission**

“To reach for new heights…

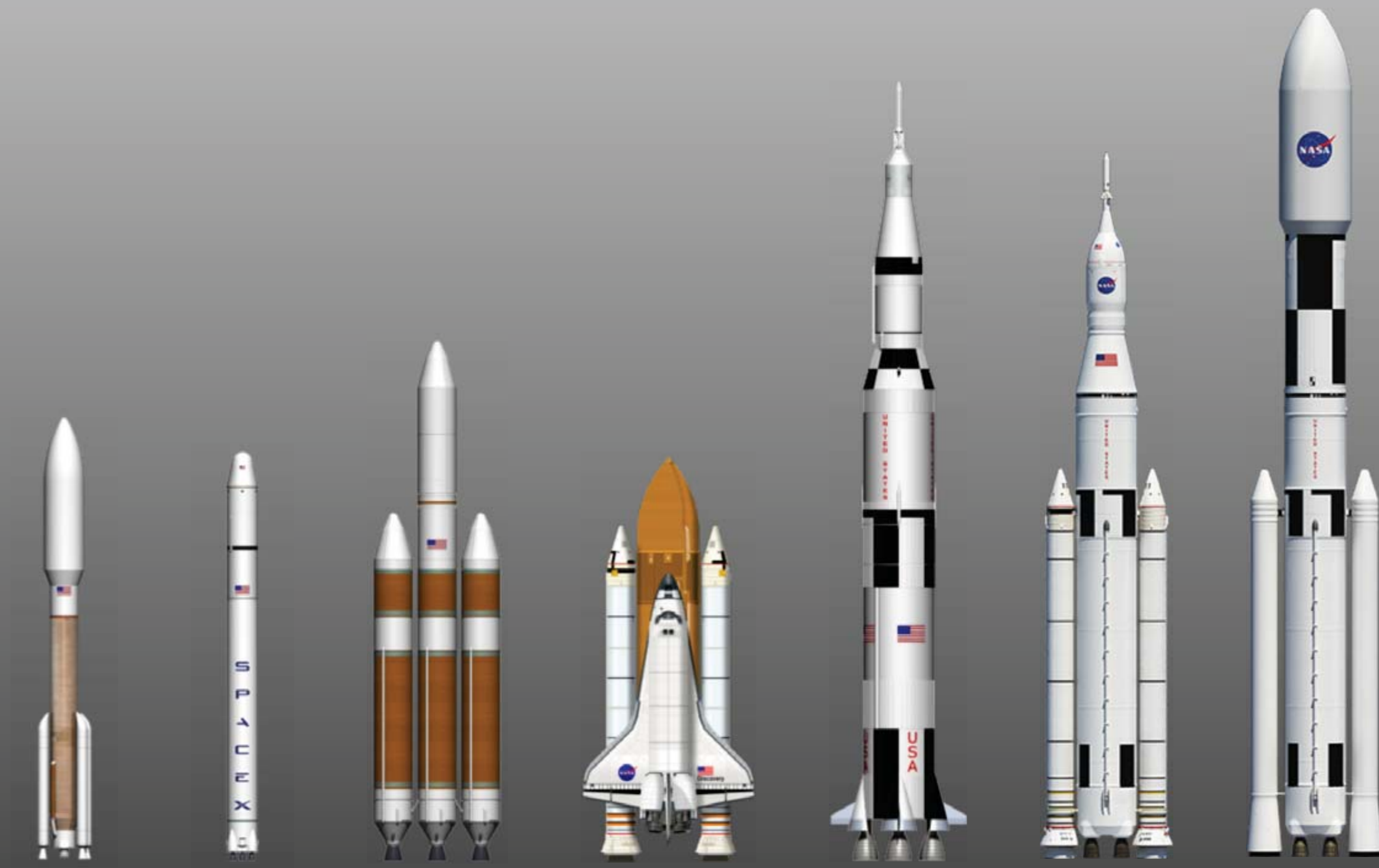
and reveal the unknown so that what we do
and learn will benefit all humankind.”

The Next **Great Ship**



Ships of exploration opened the paths **that became today's trade routes.**

Bigger Rocket = **Unrivaled Mass, Unrivaled Volume**



Enables missions **no other rocket can perform.**

NASA's Space Launch System

Orion:
Carrying astronauts into deep space

Interim Cryogenic Propulsion Stage:
Based on the Delta IV Heavy upper stage; the power to leave Earth

Core Stage:
Newly developed for SLS, the Core Stage towers more than 200 feet tall

Solid Rocket Boosters:
Built on Space Shuttle hardware; more powerful for a new era of exploration

RS-25 Engines:
16 Space Shuttle engines are already in inventory

A National **Effort**

224 Subcontracts in 30 States are **advancing technology and innovation.**

NASA's **Space Launch System**

www.nasa.gov/sls #slsinspires

SLS is the first step in the **journey to Mars**

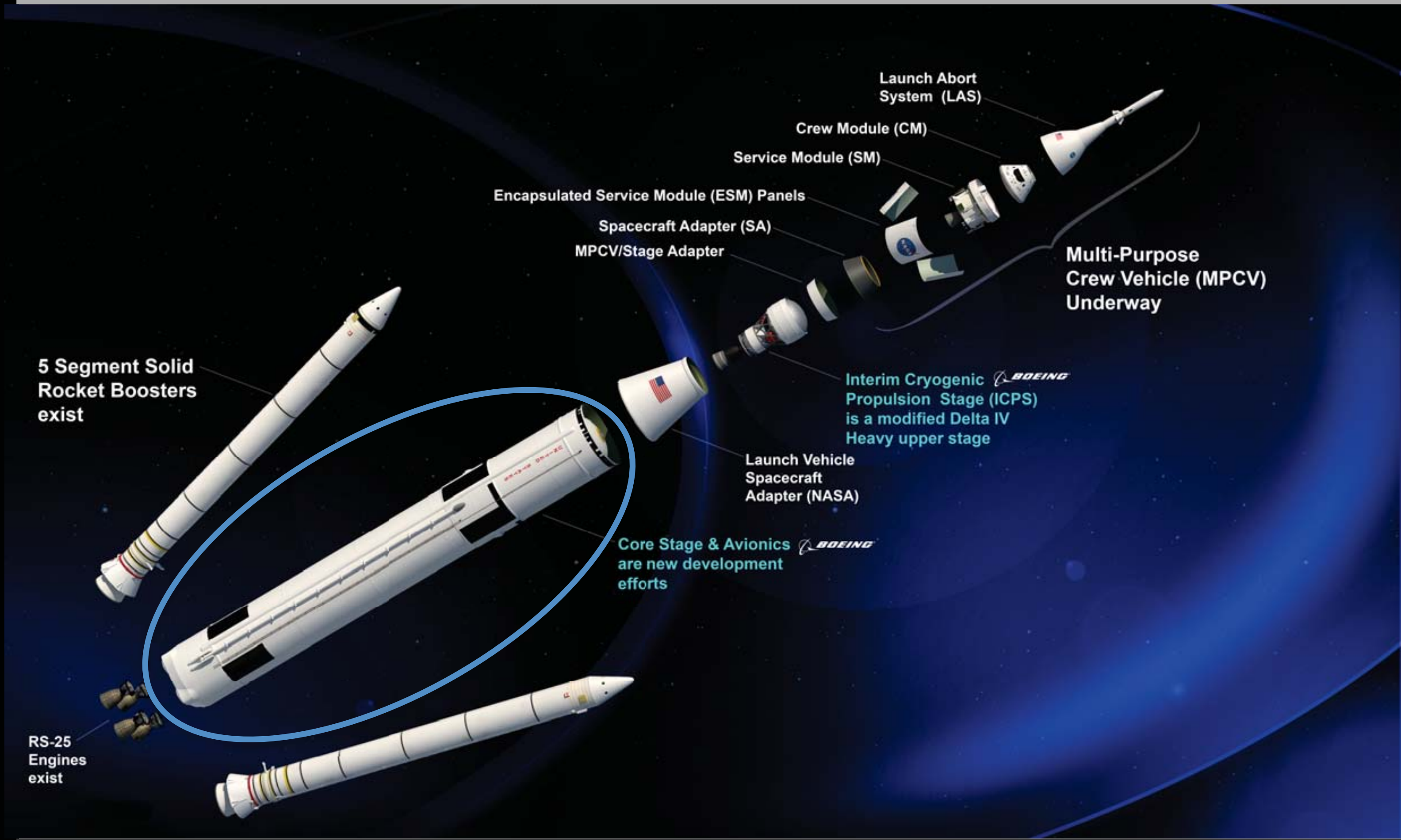
National Aeronautics and Space Administration

Space Launch System
Core Stage

Michelle Taylor, SLS Engineer
Boeing Corporation
B.S., Electrical Engineering; M.S., Aerospace Engineering
University of Alabama

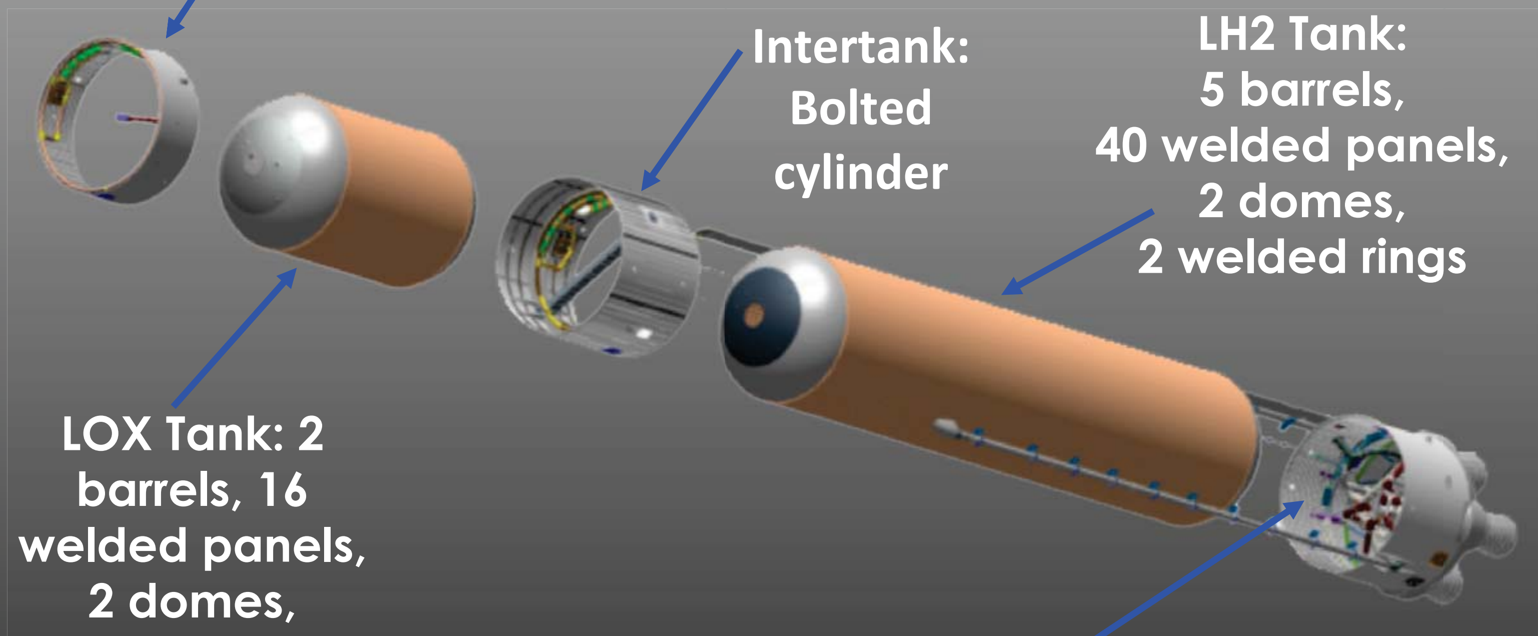
November 7, 2013

Core Stage & Avionics



NASA Marshall Space Flight Center (MSFC) Integrates SLS

Core Stage Major Structural Elements



Vertical Weld Center (VWC)

VWC Dimensions

- 41 feet tall
- 40 feet wide
- 50 feet long
- Weight –165.5 tons (not including production hardware

VWC Complete - Tool In Use

First Tank Barrel at MAF Vertical Weld Center

Enhanced Robotic Weld Tool (ERWT)

- Welds twelve gore panels together to form gore section
- Welds dome cap to top and ring to bottom of gore section to create complete dome

- The Circumferential Dome Weld Tool (CDWT) welds gore dome assemblies, rings and dome caps together to make dome assemblies

Segmented Ring Tool (SRT)

- Welds six ring segments to form one 8.4 meter ring
- Y-Rings connect tanks domes and barrels
- L-Rings connect dry structure barrels

National Aeronautics and Space Administration

Space Launch System

Rocket Engine Technology

Mike Kynard, Manager
SLS Liquid Engines Element
NASA Marshall Space Flight Center

November 7, 2013

RS-25 • The Workhorse of SLS Core Stage

RS-25 Single Engine Test on A1 Test Stand at Stennis Space Center

Core Stage Engine	*Existing RS-25 Inventory*	*New Build RS-25*
Propellant	LO2/LH2	LO2/LH2
Max power level	109%	111%
Throttle Range	65%–109%	65%–111%
Avg Thrust @ max Pwr (vac)	*512,185*lbs	521,700lbs
Min Isp @ max Pwr (vac)	450.8 (452 Avg)	450.8
Engine Mass (each)	7,816	NTE 8,156
Nom, Range MR	6.043, 5.85-6.1	6.043, 5.85-6.1
Size	96" x 168"	96" x 168"

RS-25 as the Space Shuttle Main Engine

- 3171 Total Starts
- 1,095,679 Total Seconds
- 135 flights – 100% mission success
- Reusable – Designed for 55 starts and 27,000 seconds
- First Test – 1975, Last Flight – 2011

J-2X • Upper Stage Engine for Evolved Vehicle

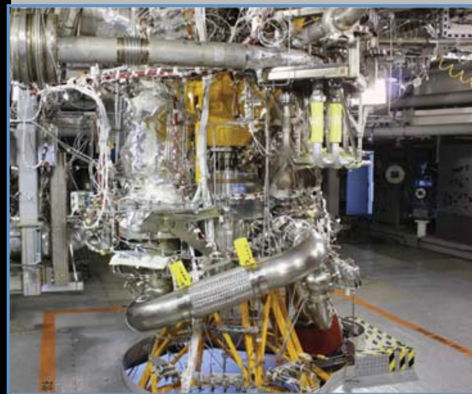
Gimbal Test for J-2X
On A1 Test Stand at Stennis Space Center

Upper Stage Engine	**J-2X**
Propellant	LO2/LH2
General Attributes	
Max power level	100.0%
Thrust (vac)	294,000 lbf
Min Isp (vac)	448 seconds
Size	92" X 131"
Engine Mass	5,400 lbm
Mixture Ratio	5.5
Secondary Power Level	~82%

Key Baseline Features

- Short nozzle implemented (285k, 435s)
  - (Capable of 294K thrust and 448s)
- Re-startable

J-2X Development • **System Testing**



Powerpack 2
- 13 tests
  - Performance characterization of turbopumps, inlet ducts, and turbine bypass system
- 6177 seconds total
  - Includes 1350 second test - longest test on A1 test stand

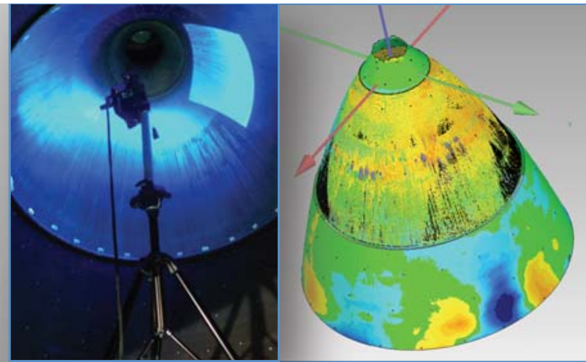
Engine 10001
- 21 tests
  - The first 10 tests performance characterization at sea level
  - Next 11 tests performance characterization with stub nozzle extension at simulated altitude
- 2718 seconds total

Engine 10002
- 6 tests on A2 test stand
  - Engine-to-engine performance repeatability characterization with stub nozzle at simulated altitude
- 7 tests on A1 test stand
  - Gimbal testing at sea level
- 5201 seconds total to date

14,096 total seconds

Single Engine Test Facility

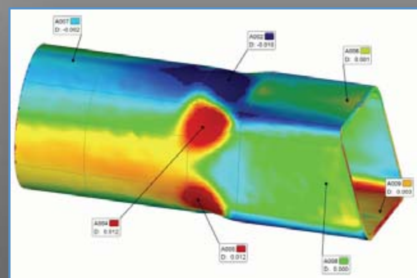
Technology We’re Developing • Structured Light Scanning Development



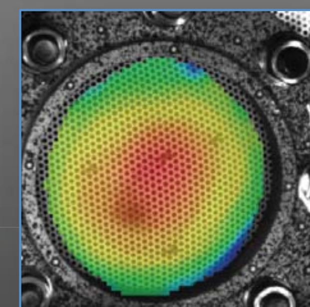
Replaced difficult measurements with scanning to help **reduce performance uncertainty** (throat and exit areas)

Training and Implementing as a new technique for Rocketdyne Personnel

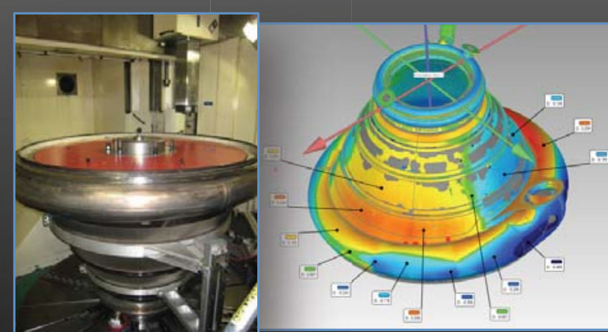
Completing study to advance structured light as a quality acceptance tool. **Implementing > 5:1 time savings.**



Structured Light Introduced to Sub-tier Vendors to modify tube dies to **integrate supply chain** (i.e. reduce turn around time for nozzle assembly)



Developing new optical techniques to augment traditional engine measurements



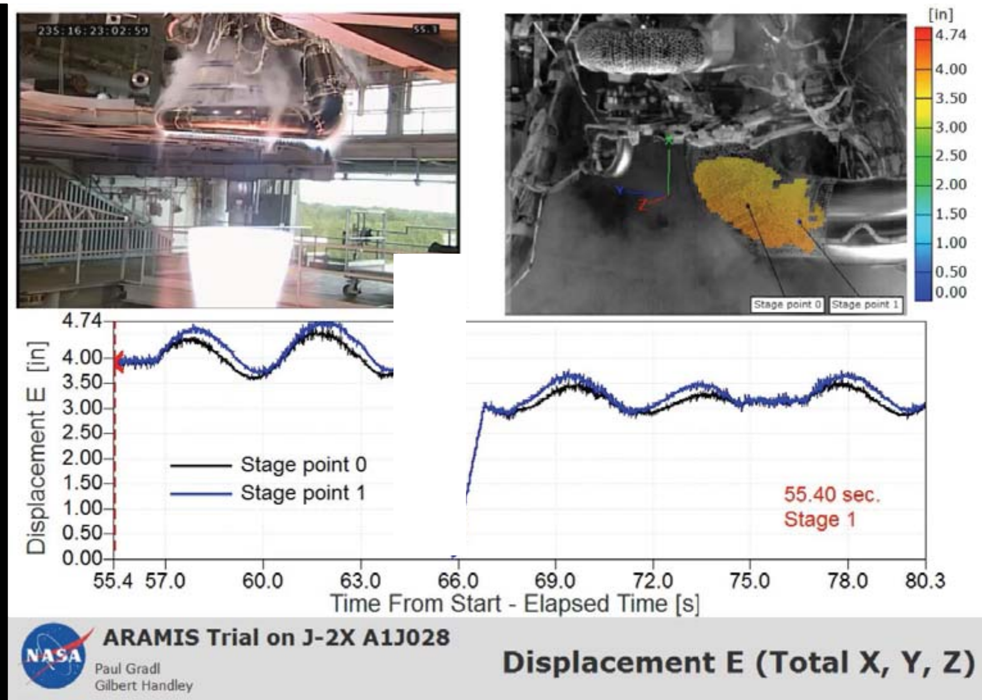
Structured Light Used to **Generate Machining Code** and Match Machine at PWR

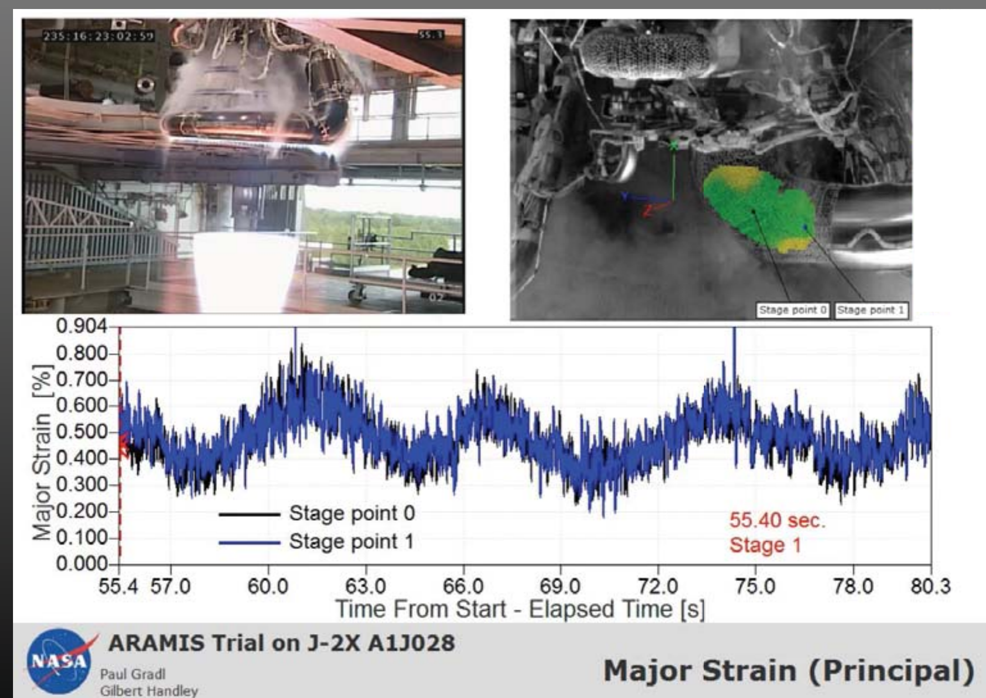
Reducing the Development Cycle for Hardware

Technology We're Developing

•

Structured Light





Technology We're Developing

•

Selective Laser Melting

Technology We’re Developing

•

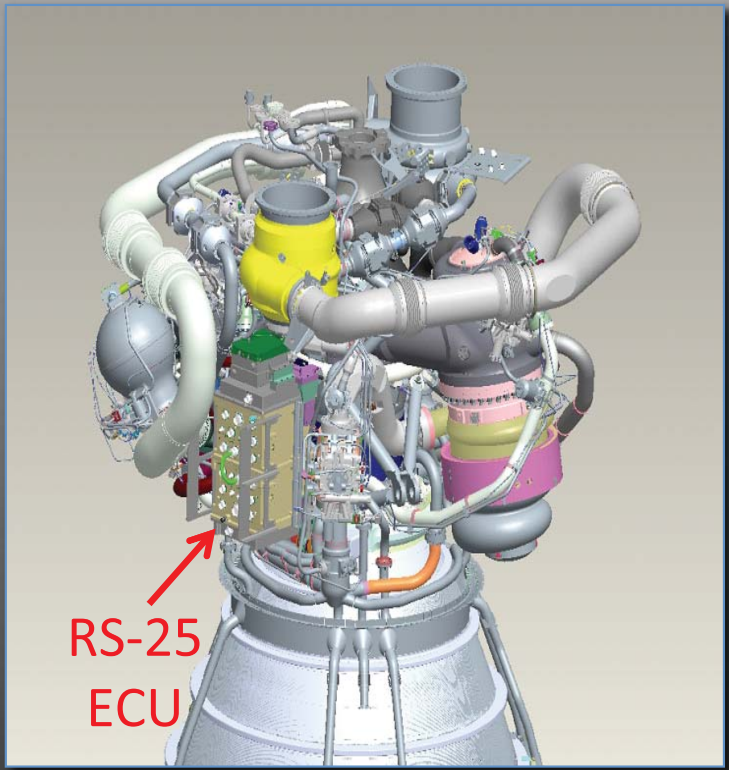
Selective Laser Melting

Engine Controller Unit (ECU)

- **ECU function**
  - Controls thrust and mixture ratio
    - Open and closed loop
  - Continuously monitors engine health
  - Provides electric power to control elements, sensors, and effectors
  - Accepts commands from and reports data to vehicle computers

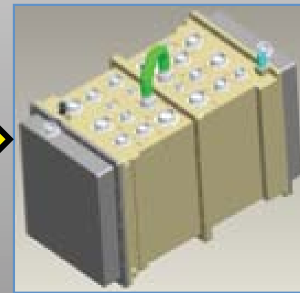
- **Challenge:** Heritage controller incompatible with new vehicle

- **Solutions**
  - Design new controller rather than adapt old
  - Leverage J-2X design for "universal controller"



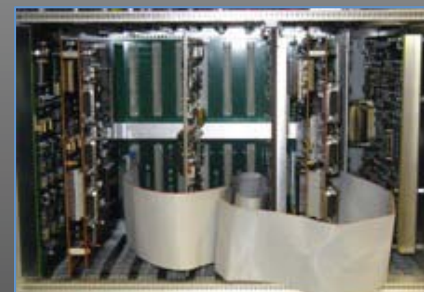
Engine Controller Unit (ECU) (Continued)

SSME Engine Controller Unit

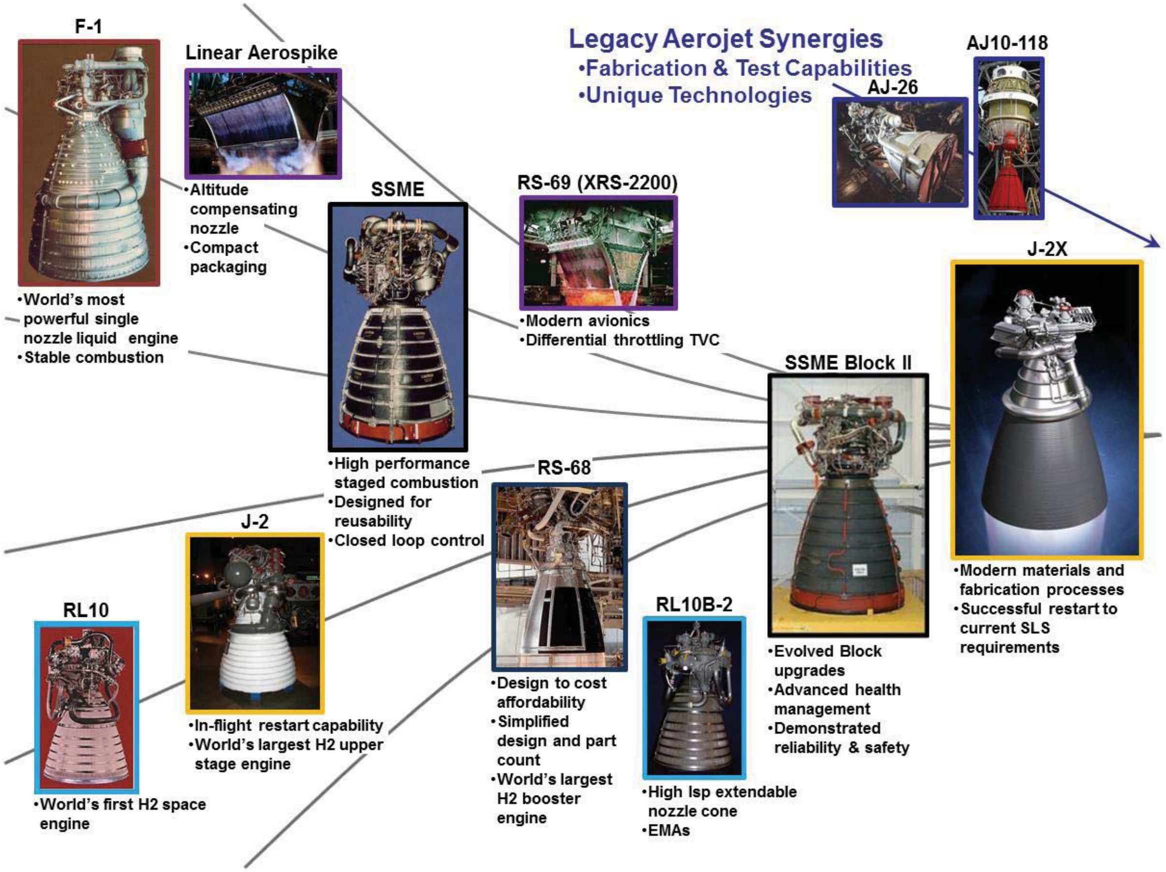


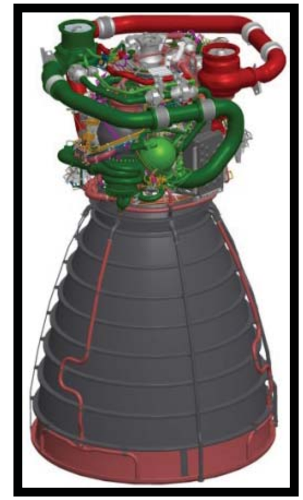
RS-25 ECU
Basic design supports RS-25 and J-2X

J-2X Engine Controller Unit



Roadmap to Improved RS-25





- Leverages Nation's wealth of propulsion experience
  - Maintain 100% mission success
  - Introduce high maturity affordability enhancements
  - Sustainable design, processes and supply chain
  - Evolve into SLS to meet future mission needs

Delivery of affordable RS-25 engines is key to SLS success. J-2X represents the current state of NASA/AR capability to affordably design, develop, test, evaluate, *and* manage human-rated flight-qualified liquid rocket engines.

National Aeronautics and Space Administration

Space Launch System

Systems Engineering & Integration

Garry Lyles, Chief Engineer
SLS Program Office
B.A. in Mechanical Engineering, University of Alabama
Class of 2010 Distinguished Engineering Fellows

November 7, 2013

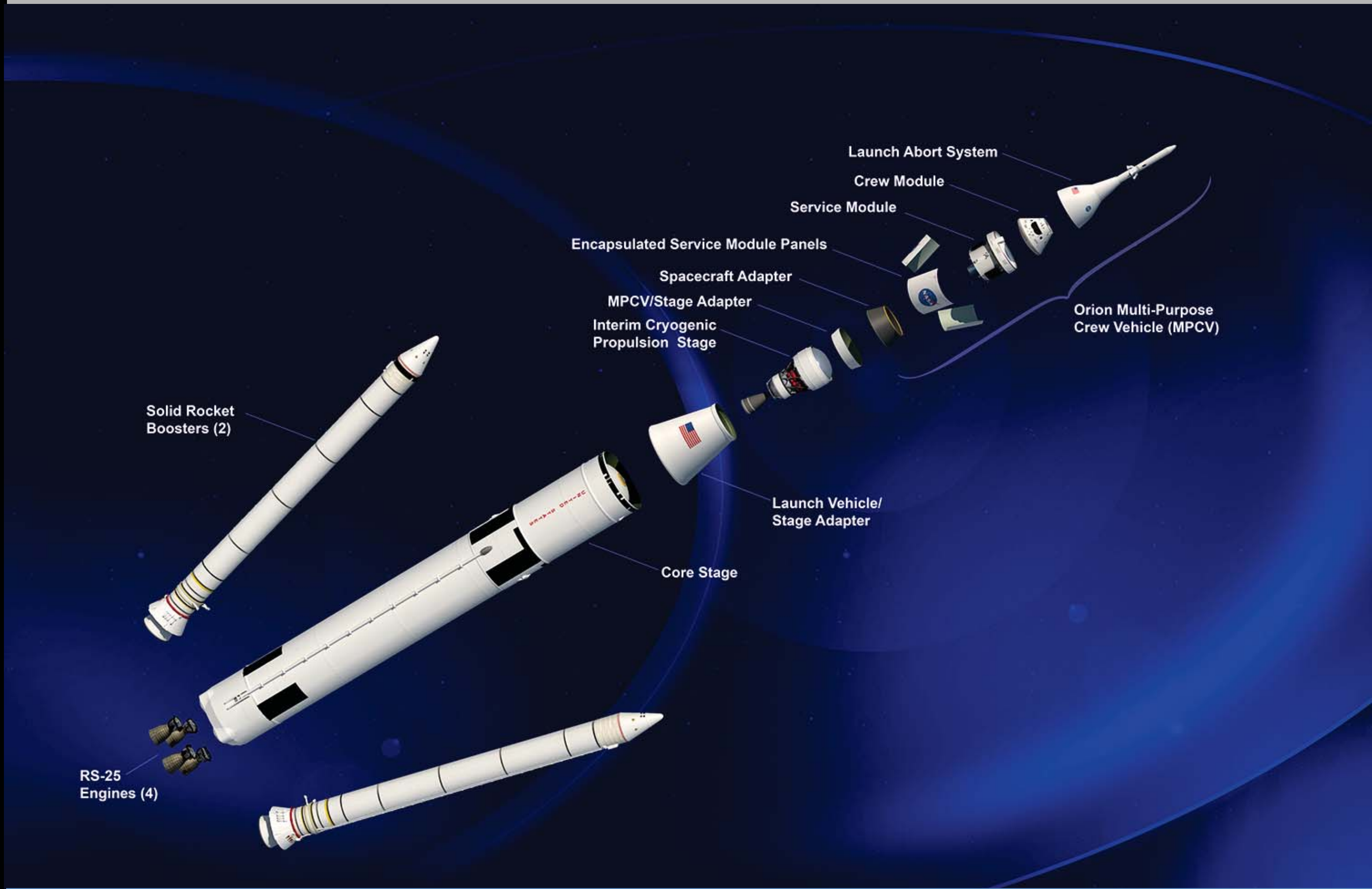
"We're going to get this country — and the world — exploring beyond low-Earth orbit very shortly."

— Dan Dumbacher
Deputy Associate Administrator
Exploration Mission Directorate

A National Infrastructure Asset

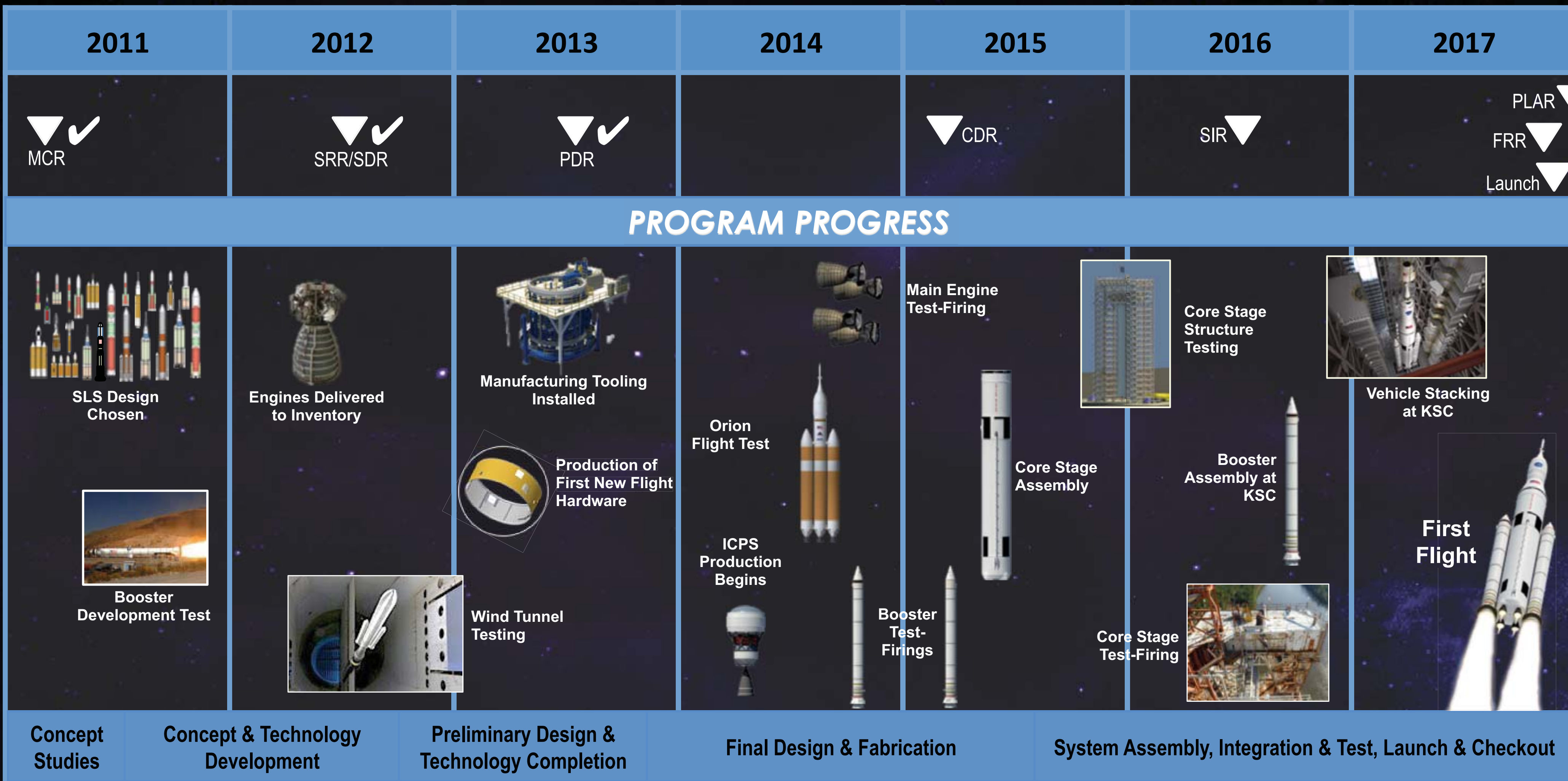
Exploration Mission 1

70 Metric Ton Expanded View



Initial Capability Builds on Heritage Hardware

SLS Development Schedule



MCR: Mission Concept Review	CDR: Critical Design Review
SRR: System Requirements Review	SIR: System Integration Review
SDR: System Definition Review	FRR: Flight Readiness Review
PDR: Preliminary Design Review	PLAR: Post-Launch Asses. Review

Communication and Integration

Accountability and Responsibility

- Strong focus on leadership at all levels
- Organized to balance functional expertise and cross-functional integration
- Chief Safety Officer and staff provide guidance, analysis, and oversight/insight
- Chief Engineer serves as lead designer, with staff focused on technical integration
- Early integration of production considerations
- Entire organization focused on stakeholder value

SLS Systems Engineering & Integration Organization	Systems Engineering	Vehicle Management	Structures & Environments	Propulsion	Production	Integrated Avionics & Software	Operations	Test	Safety & Mission Assurance
Program Chief Engineer (CE)	Lead Systems Engineer (LSE)	Discipline Lead Engineer (DLE)	DLE	DLE	DLE	DLE	DLE	DLE	Chief S&MA Officer (CSO)
Stages Element Chief Engineer (ECE)	Element LSE (ELSE)	Element DLE (EDLE)	EDLE	EDLE	EDLE	EDLE	EDLE	EDLE	Element CSO (ECSO)
Booster ECE	ELSE	EDLE	EDLE	EDLE	EDLE	EDLE	EDLE	EDLE	ECSO
Engines ECE	ELSE	EDLE	EDLE	EDLE	EDLE	EDLE	EDLE	EDLE	ECSO
Integrated Spacecraft & Payload ECE	ELSE	EDLE	EDLE	EDLE	EDLE	EDLE	EDLE	EDLE	ECSO
Advanced Development ECE									

Top Technical Issues

Loads and Environments	Performance Threats	Interfaces
• ICPS Engine/Actuator Loads	• Propulsion Performance	• Core Stage Engine
• Predicted Core Stage acceleration	• Mass Growth	• BSM Cover
• Booster forward skirt	• Loads	• Core Stage
• MPCV designed to Ares loads		• Booster Separation
• Updated acoustic environments		• Core Stage Engine
		• FTS Pyro Delay

DAC-3 Touches Majority of Open Issues

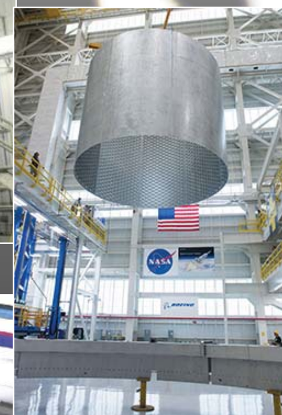
Meeting Our Commitments & Exceeding Expectations

On Course for First Flight In 2017

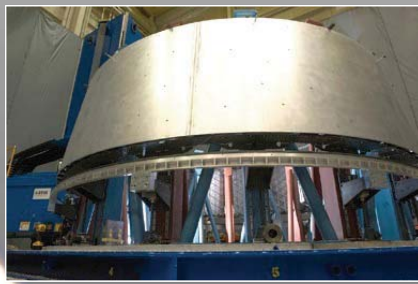
Engines
Tested selective laser melted part on J-2X at Stennis Space Center (March 2013)

Boosters
Conducted Thrust Vector Flight Control Test at ATK in Promontory, UT (Jan 2013)

Core Stage
Transferred Core Stage test panels to Michoud Assembly Facility (MAF) in New Orleans (Spring 2013)



First Core Stage barrel section welded at MAF (July 2013)



Spacecraft & Payload Integration
Conducted fit-check of the Multi-Purpose Crew Vehicle Stage Adapter at the Marshall Space Flight Center for 2014 Exploration Flight Test (June 2013)

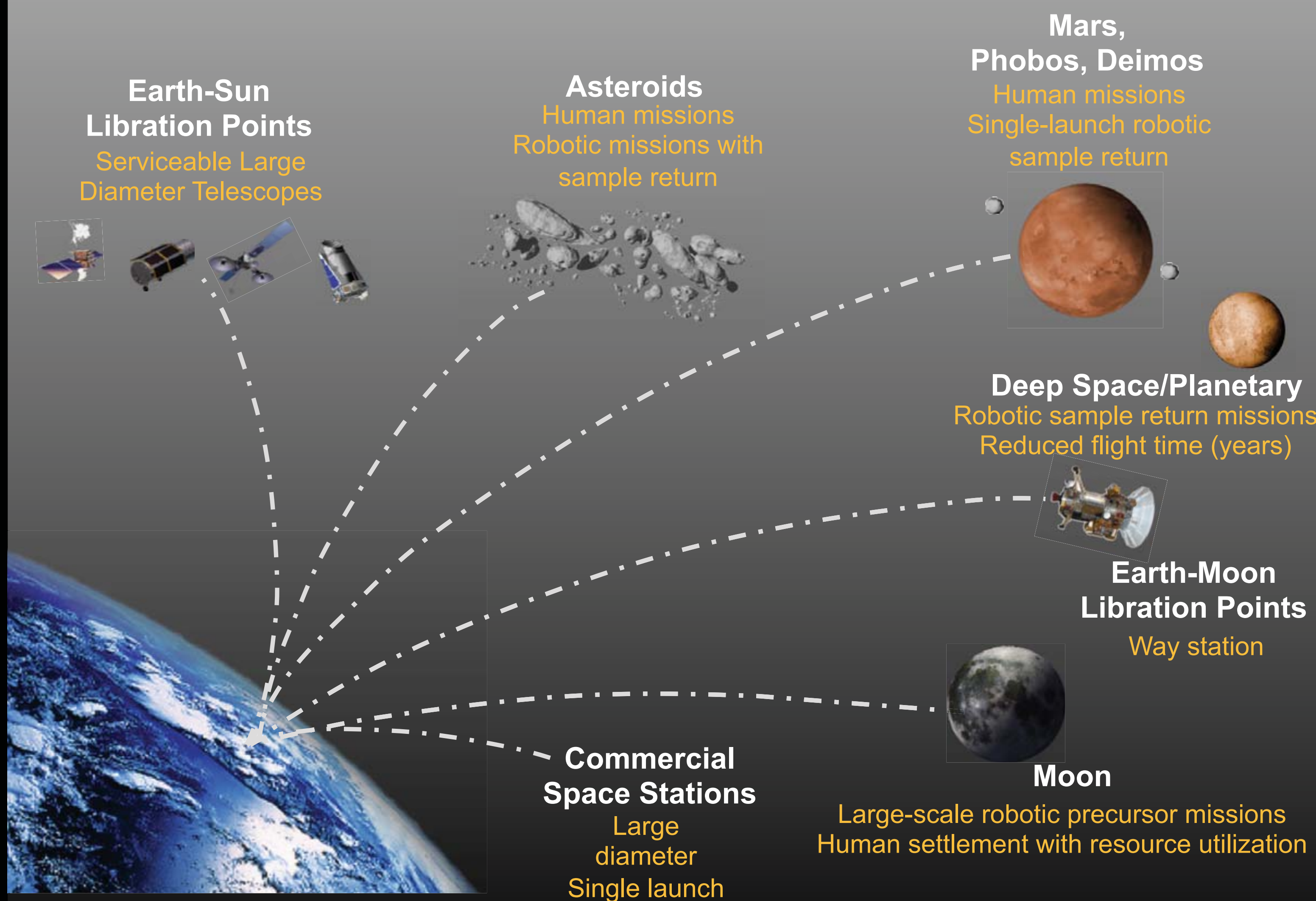
Advanced Development
Conducted F-1 engine hot-fire testing at Marshall (Jan 2013)

Systems Engineering & Integration
Tested buffet model in Langley Research Center's Transonic Dynamics Wind Tunnel (Jan 2013)

"Awesome...huge step...stay focused and keep designing and building. December 2017 is closer than we think.

—William Gerstenmaier,
Human Exploration and Operations Director,
July 31, 2013

Islands in Our Ocean



Powering the Future of Exploration

Aerospace Engineering & Mechanics

Chemical & Biological Engineering

Computer Science

Mechanical Engineering

Civil, Construction & Environmental Engineering

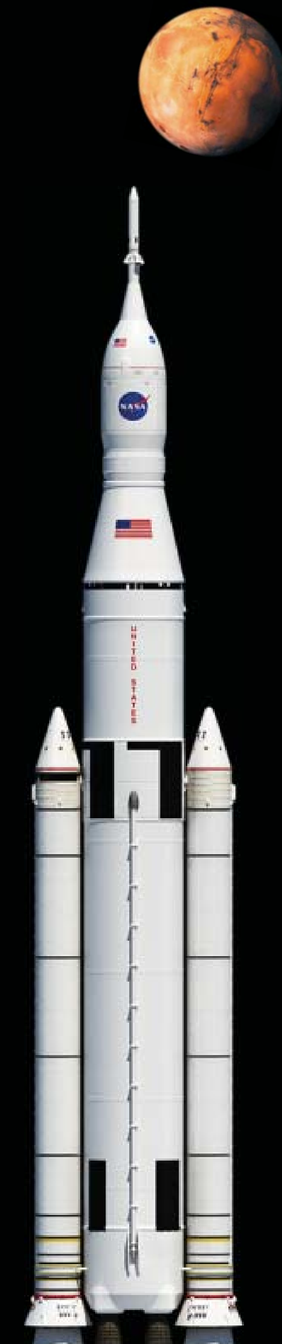
Electrical & Computer Engineering

Metallurgical & Materials Engineering

"Man cannot discover
new oceans
unless he has the
courage to lose
sight of the shore."

Join us on
the journey

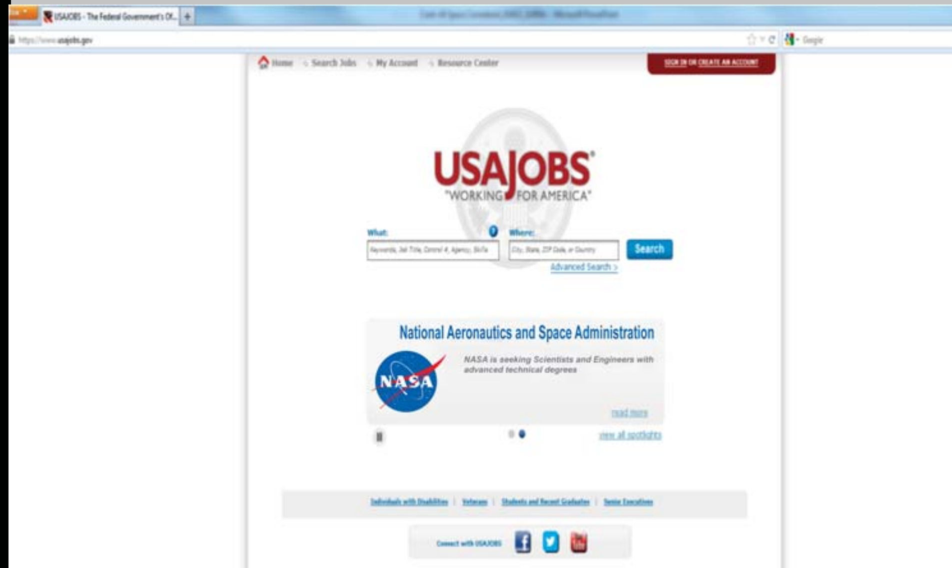
www.nasa.gov/sls
www.twitter.com/nasa_sls
www.facebook.com/nasasls



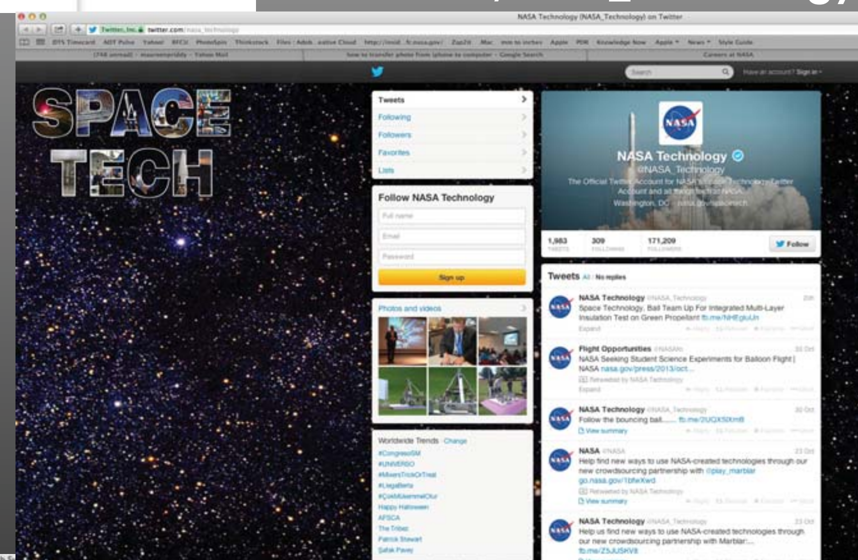
[redacted]

Connect Now.

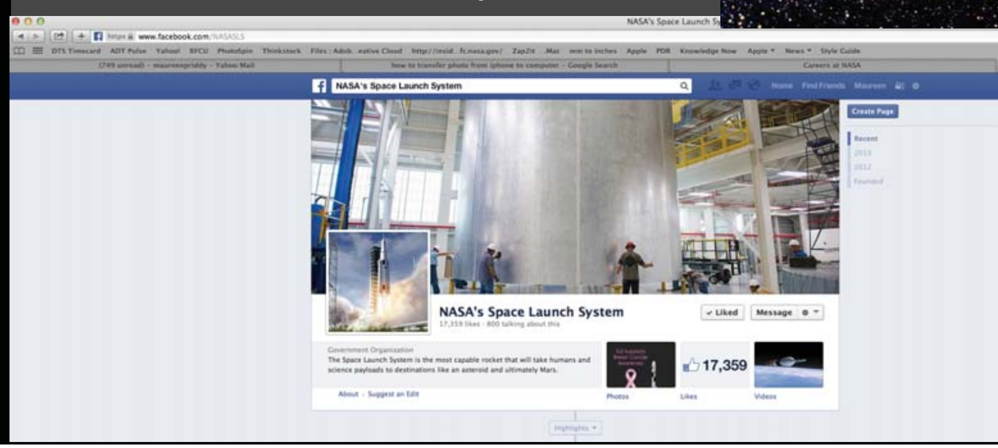
www.usajobs.gov



twitter.com/nasa_technology



www.facebook.com/NASASLS



www.usajobs.gov/studentopps/default.htm

Connect Now.

Connect Now.

https://intern.nasa.gov/ossi/web/public/main/

Questions & Answers